Radiation Hard Scintillator Research and Development Studies at the University of Iowa

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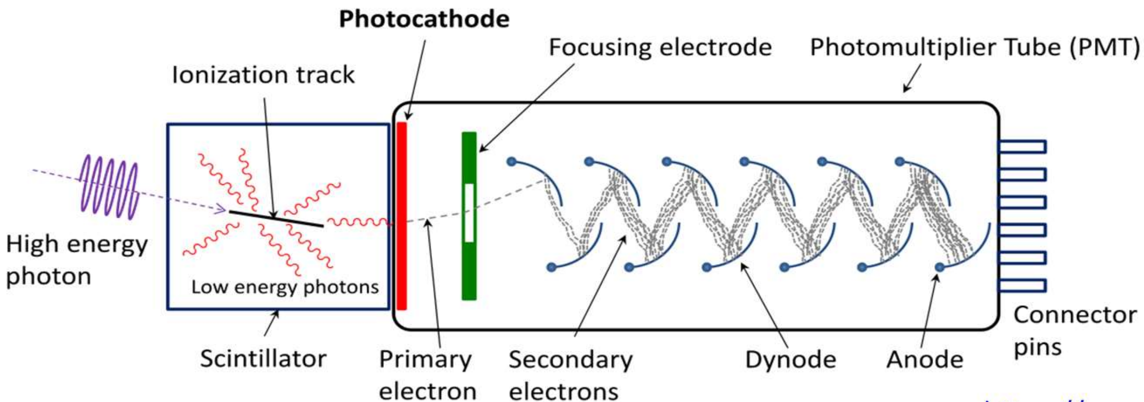
OUTLINE

Introduction

- A scintillator is a material that fluoresces when it is hit by ionizing radiation such as an accelerated charged particle.

- In order for scintillators to be useful they are usually coupled with a Photomultiplier Tube (PMT) or a Silicon Photomultiplier (SiPM).

- Usually a PMT is placed close to a scintillator and the scintillations (emitted photons) are guided into the PMT. The photons are then in essence, “converted” to electrons where their signal is then greatly multiplied and eventually read out as an electronic signal at the other end of the tube.



https://en.wikipedia.org/wiki/Photomultiplier

Motivation for Radiation Hard Scintillator R&D

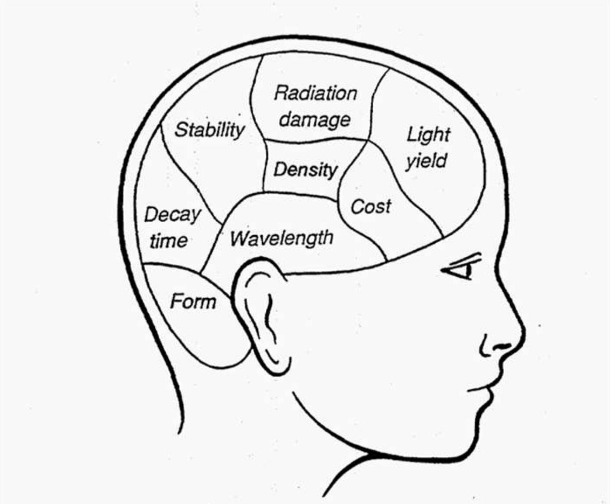
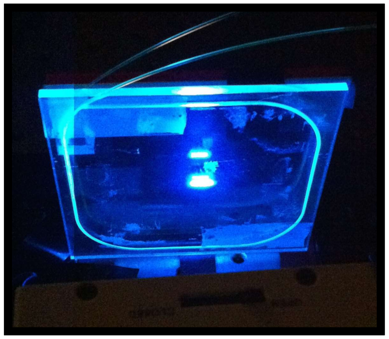
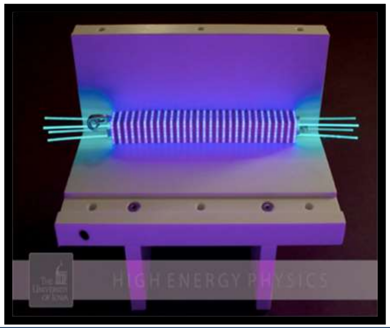


Figure 2. Properties of scintillators to be considered when selecting materials.

What are we looking for?

- ✓ Compact
- ✓ High light yield
- ✓ High resolution
- ✓ Radiation resistant
- ✓ Fast
- ✓ Cost effective Scintillators.





Our goal is:

- To provide a Radiation Hard scintillator specifically for use in the CMS experiment, however it is not limited to the CMS experiment.
- To provide a Radiation Hard scintillator for use in other fields such as Medical and Nuclear Physics
- To research new and refine existing scintillator production techniques.

Reference: E. Tiras, New Perspectives 2016

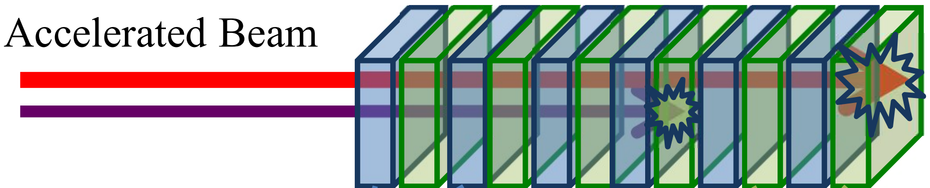
In Depth Example: Calorimeter Design Ref. E. Tiras NP Talk

Reference: E. Tiras, New Perspectives 2016

Calorimeters;

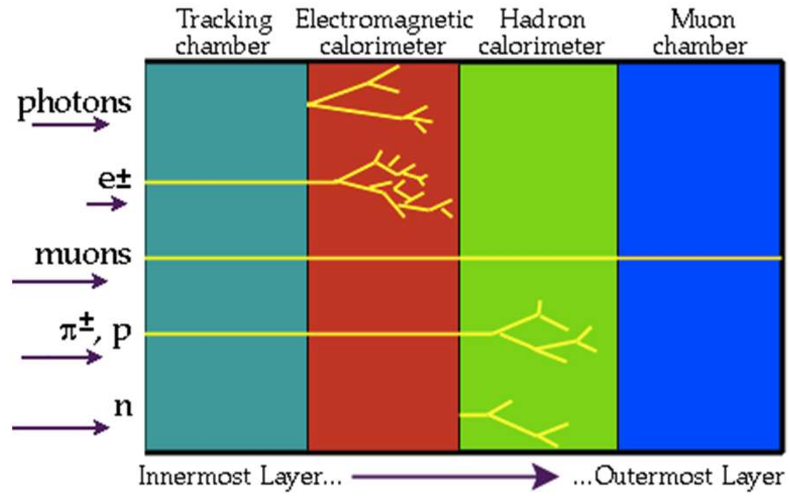
- stop particles to measure the energy of them (charged and neutral particles)
- are too large to absorb as much particle energy as possible

Accelerated Beam

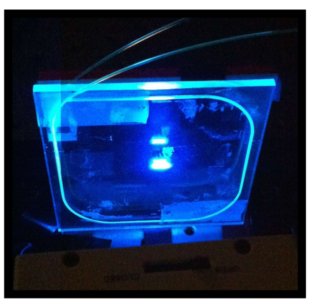


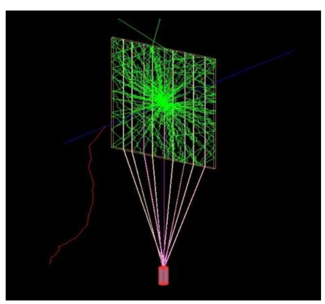
Absorbers:
lead, tungsten, etc.
(slow down particles)

Scintillators:
plastic, quartz, etc.
(produce photons called scintillation)

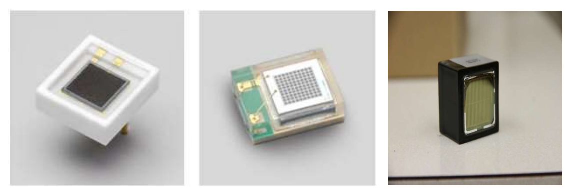


- different geometries:





- different photodetectors:



SiPM PMT

Previous Research at the University of Iowa

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ELSEVIER

Using LEDs to stimulate the recovery of radiation damage to plastic scintillators

CrossMark

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JINST

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Radiation damage and recovery properties of common plastics PEN (Polyethylene Naphthalate) and PET (Polyethylene Terephthalate) using a ^{137}Cs gamma ray source up to 1.4 Mrad and 14 Mrad

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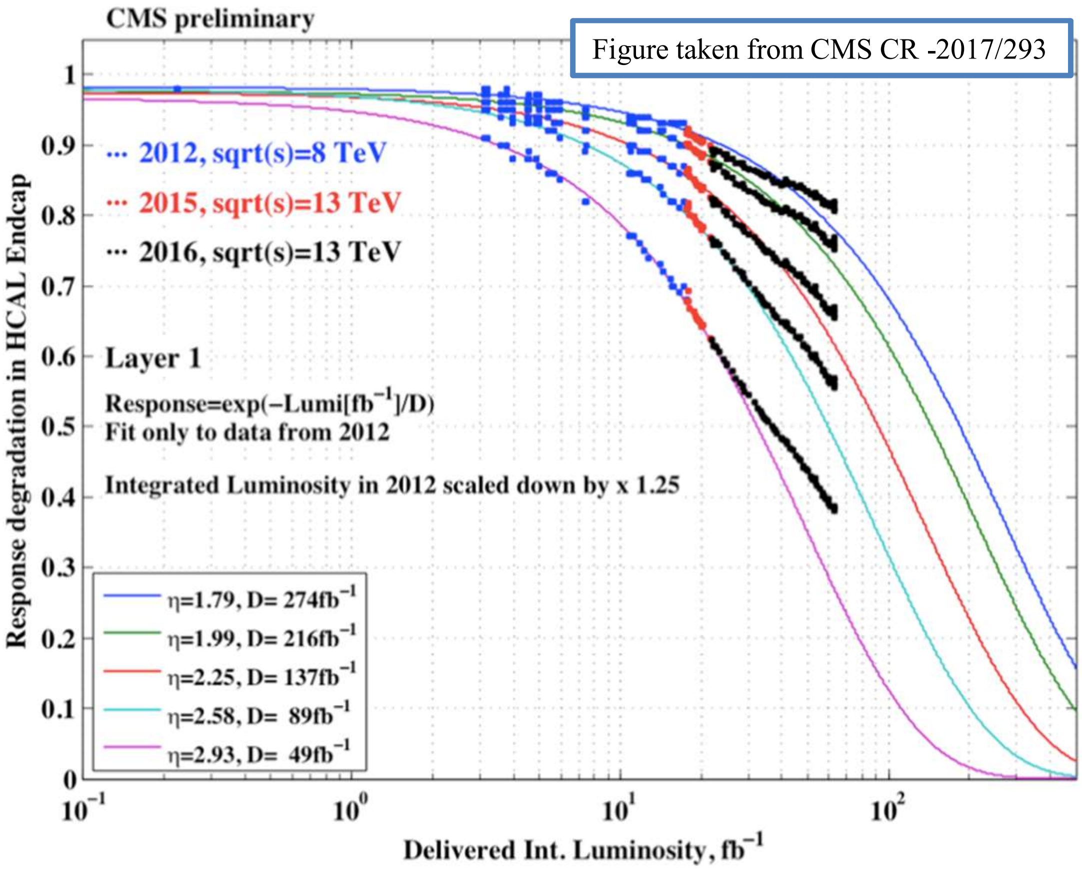
- Quartz plates coated with various organic materials such as p-Terphenyl (pTp), Gallium-doped Zinc Oxide (ZnO:Ga), Anthracene (An)

- Plastic scintillators such as PEN, PET and HEM

Radiation Resistance is Key

- Because collision energy and luminosity (# of particles/sec.) are increasing, so too is the total radiation level increasing.
- Enter Scintillator-X, a proprietary radiation hard scintillator currently in research and development at the University of Iowa High Energy Physics Group.



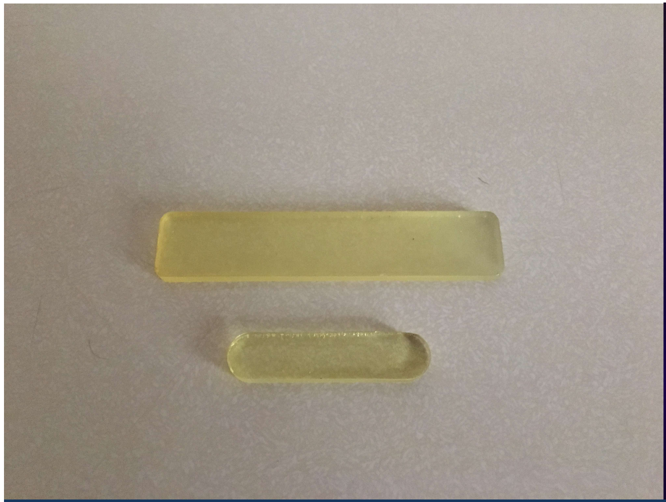
- It is clear that as luminosity increases the effectiveness of the scintillators decreases.
- Therefore it would be nice to have a radiation resistant scintillator for CMS.

Scintillator-X Production Process Summary

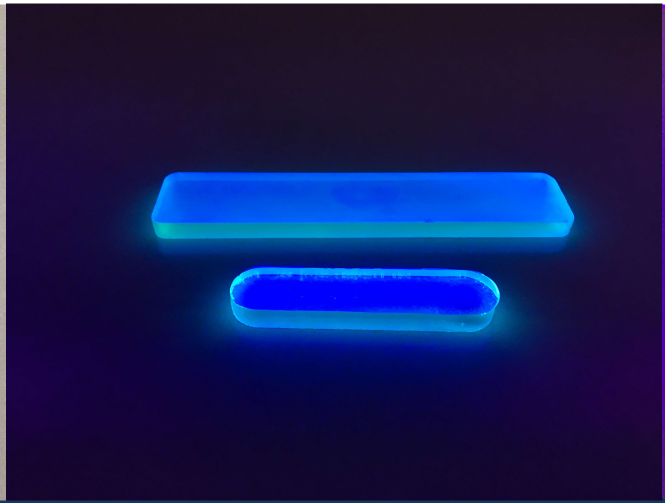
1. Lab-Prep
2. Pre-Cure Stage
3. Curing Stage
4. Post-Cure Stage
5. Clean-Up

*It is vital that in addition to the electronic temperature cycle data taken, we also take detailed notes along the way.

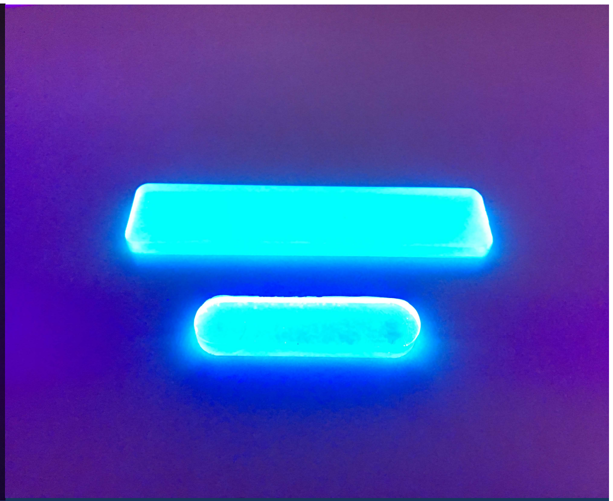
~8 Hours after post cure "white-light"



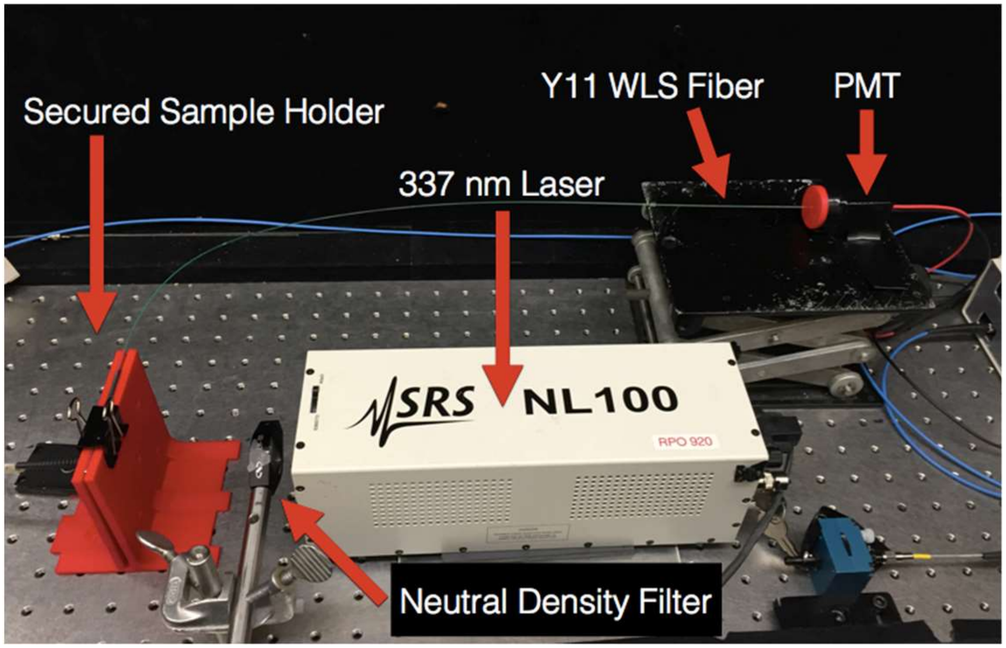
~8 Hours after post cure "black-light"

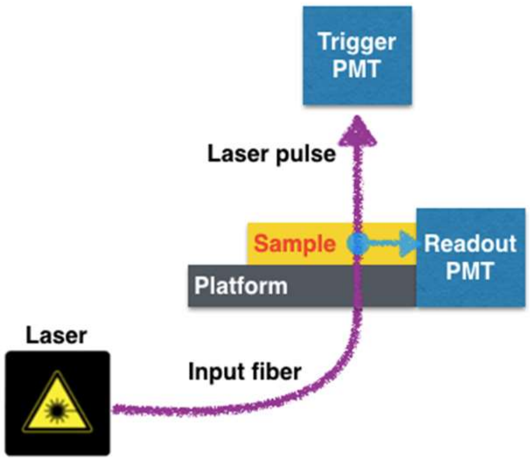


~2 Weeks after post cure "black-light"



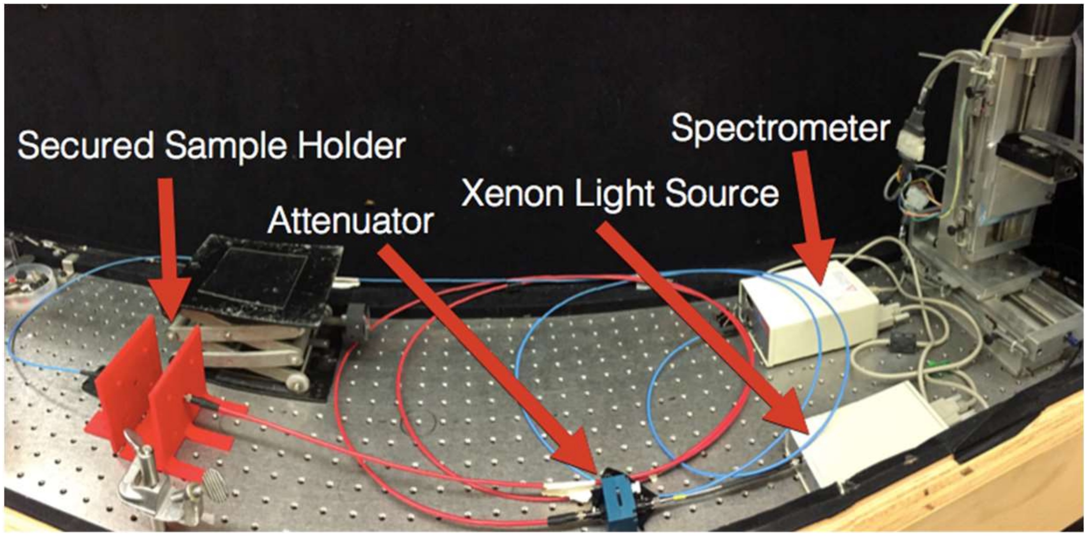
Characterization Tests at the University of Iowa



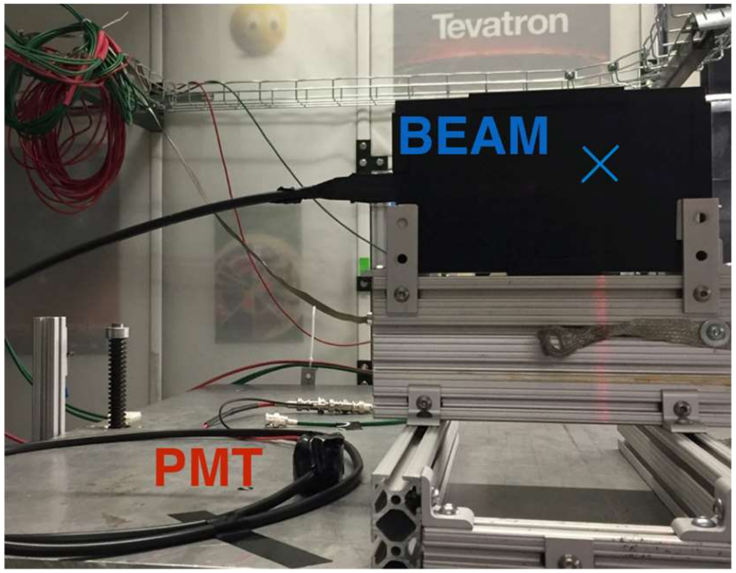


Scintillation Test Setup

Absorption and Transmission Test Setup

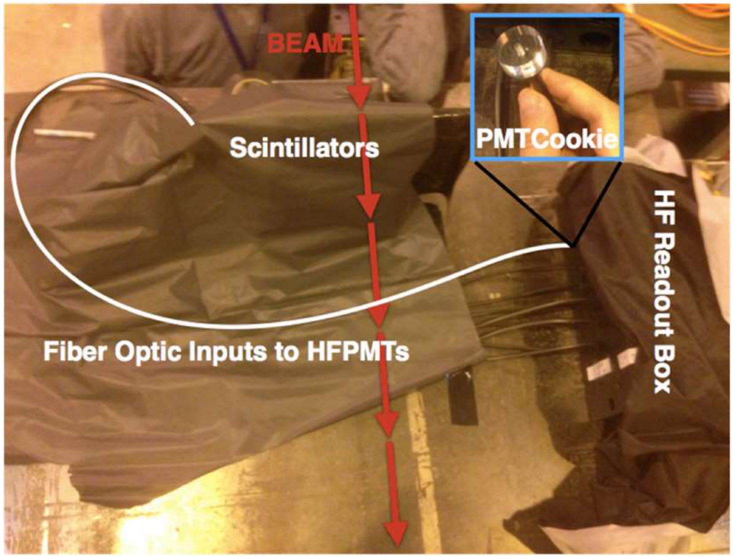


Experimental Set-Up at Fermilab & CERN Test Beams



Fermilab Test Beam Facility (FTBF)

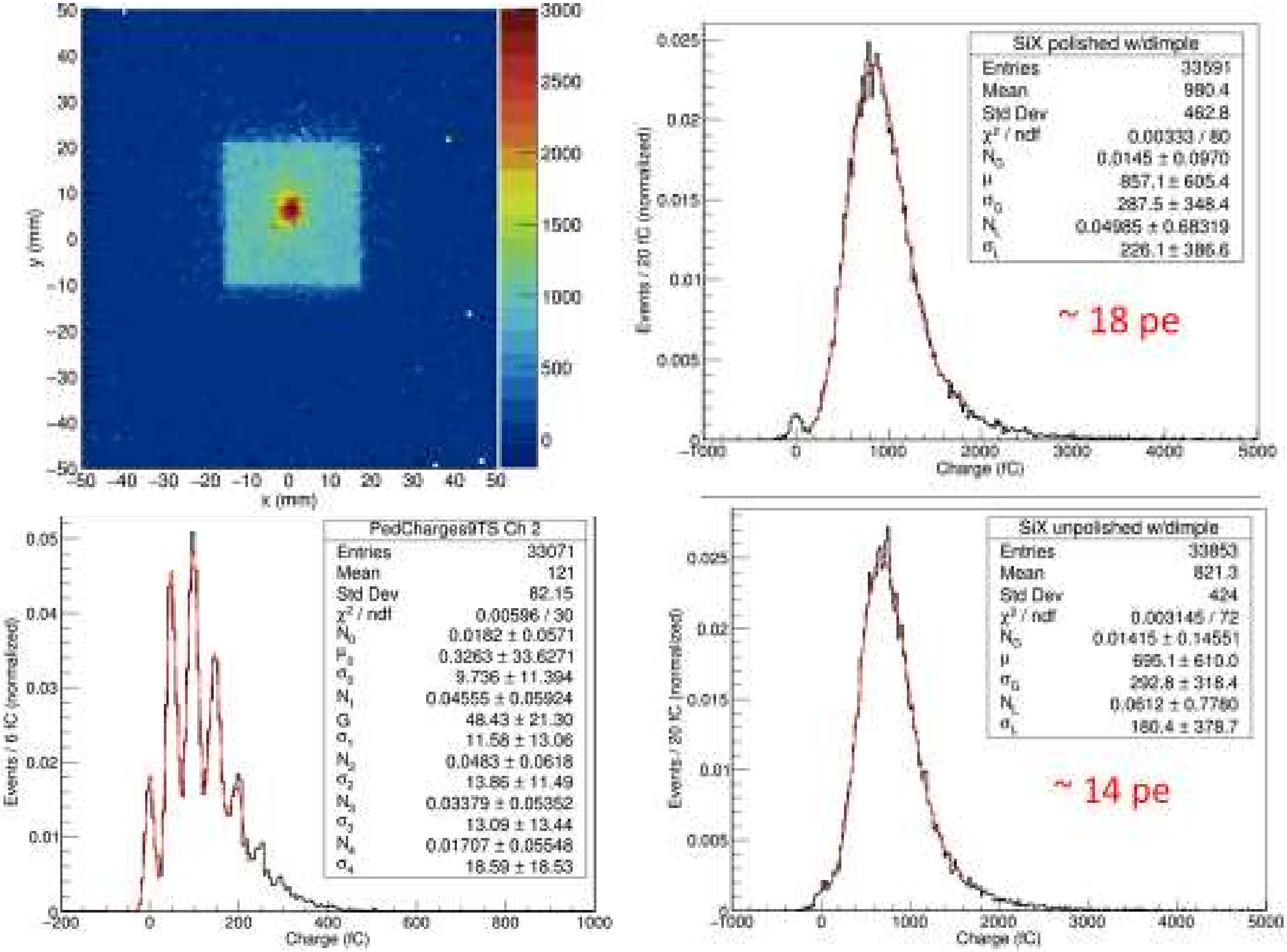
- Primary beam, 120 GeV protons
- Secondary beam, 1-32 GeV, electrons, positrons, pions, etc.



CERN H2 Test Beam Site

- Primary beam, 400 GeV protons
- Secondary beam, 10-360 GeV electrons, hadrons and muons.

CERN 2017 H2 HCAL Test Beam Results



Fit to a Gaussian + Landau

Summary & Conclusion

- Scintillator-X appears to be a promising option thus far.
- We still have room to improve our production process.
- Rigorous analysis work is still in progress.
- There is still a lot of fine tuning to be done.
- Preliminary patent has been applied for.

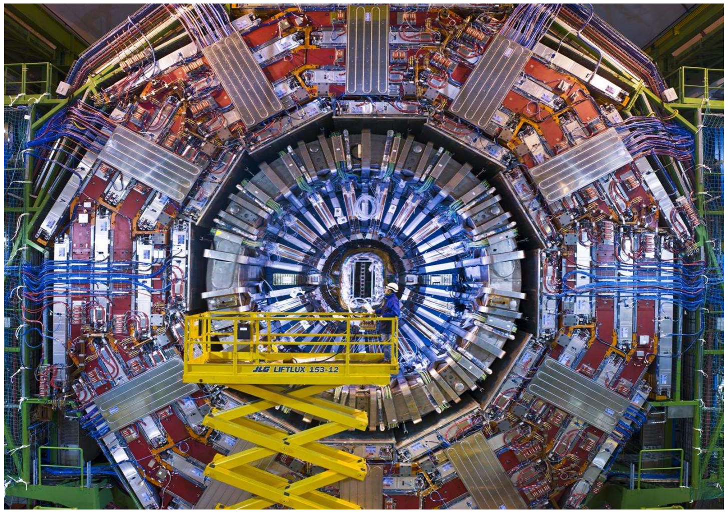
Back Up Slides

Examples of Technology That Utilizes Scintillators

University of Iowa PET Scan Machine

Positron Emission Tomography (PET) utilizes scintillators to aide in the treatment of various medical ailments including cancer.

https://www.iibi.uiowa.edu/pet-center



CMS

The Compact Muon Solenoid (CMS) Experiment, part of the Large Hadron Collider (LHC) at CERN. While not every sub system utilizes scintillators, a good deal of them such as HCAL do. For obvious reasons a radiation resistant scintillator would be quite handy for such applications.

https://home.cern/sites/home.web.cern.ch/files/image/experiment/2013/01/cms_0.jpeg